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Background conditions for the October 29, 2003 solar flare by the AVS-F apparatus data

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Abstract

The background model for AVS-F apparatus onboard CORONAS-F satellite for the October 29, 2003 X10-class solar flare is discussed in the presented work. This background model developed for AVS-F counts rate in the low- and high-energy spectral ranges in both individual channels and summarized. Count rate were approximated by polynomials of high order taking into account the mean count rate in the geomagnetic equatorial region at the different orbits parts and Kp-index averaged on 5 bins in time interval from −24 to −12 hours before the time of geomagnetic equator passing. The observed averaged counts rate on equator in the region of geomagnetic latitude ±5° and estimated minimum count rate values are in coincidence within statistical errors for all selected orbits parts used for background modeling. This model will used to refine the estimated energy of registered during the solar flare spectral features and detailed analysis of their temporal profiles behavior both in corresponding energy bands and in summarized energy range.

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1. The AVS-F apparatus short description

The AVS-F apparatus (Amplitude-Time Spectrometry of the Sun) [1, 2] was installed onboard the specialized automatic station CORONAS-F [3-5]. The apparatus was intended for the solar flares hard X-ray and gamma-ray

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emission characteristic studies and for gamma-ray bursts detection. AVS-F instrument was the system of electronics for onboard data acquisition from the SONG-D (Solar Neutrons and Gamma-quanta) [6] scintillation detector developed by SINP MSU, and X-ray semiconductor spectrometer XSS-1 [7, 8, 9] constructed by MEPhI and IKI RAS in cooperation. The AVS-F apparatus was developed basing on the block system of electronics [1, 2, 7] and included electronics crate with power supplies and a set of functional blocks [10]. Functional diagram of the AVS-F experiment is presented at Fig. 1.

The extensive background models both in low and high-energy bands of AVS-F apparatus are discussed in the presented article. It allows to refine registered during the October 29, 2003 solar flare spectral features positions and detailed analysis of their temporal behavior.

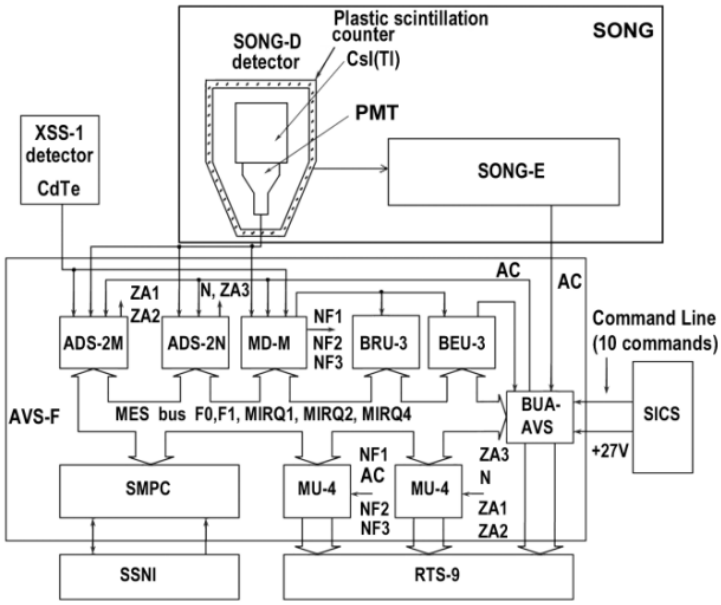

Fig. 1 Functional diagram of the AVS-F experiment.

2. The October 29, 2003 solar flare

The October 29, 2003 solar flare of X10 class began at 20:38 UT, ended at 20:55 UT according to the data of the detectors onboard the GOES series satellites [15] and was one of the series of October–November 2003 flares, originated from the active region NOAA 10486 (its coordinates were S15, W02). This flare temporal profiles shape in the hard X-rays and gamma-energy bands in the operational ranges of the AVS-F apparatus has more complicated shape, then ones in the soft X-bands accordingly to the data of the detectors onboard the GOES series satellites [13, 14]. Maximum of the soft X-rays of this flare was observed at 20:49 UT, but it corresponded to minimum in the energy range of 0.1–17 MeV, and maxima in this range were observed during the rise (4 maxima) and decreasing (2 minima) phases of the soft X-rays emission and were not associated with the features of its temporal profile in the soft X-band [14]. Thin structure with characteristic timescale of 30÷160 s was observed at the summarized temporal profile of this flare in the energy range of 0.1–17 MeV by the AVS-F apparatus data [14]. During this flare, 5 spectral lines complexes were identified in the summarized energy spectrum in the ranges of 0.81-0.94 MeV, 1.51-1.74 MeV, 2.6-3.4 MeV, 4.0-5.0 MeV, 5.3-6.9 MeV according to the preliminary data processing [13].

3. Procedure of background subtraction for AVS-F apparatus

The analysis procedure of temporary behaviour of the lines registered in the event by the AVS-F apparatus data includes background subtraction in each spectral channel. Previously only integral background subtraction in a wide energy range was done for this flare. This article presents total background model in 82 channels of the low-energy range and 64 channels of the high-energy range. Typical dependence of the summarized AVS-F counts rate on geomagnetic latitude in the low- and high-energy gamma-bands is presented at Fig. 2. There are well-defined Earth radiation belts, polar caps and SAA regions (1, 2 and 3 at Fig.2 correspondingly) in the high-energy and low-energy bands. Also the areas of precipitated from the external Earth radiation belt electrons bremsstrahlung registration in the low-energy gamma-band were identified (4). The equatorial regions (5) were more interest for study because of the most favorable conditions for the burst events (solar flares and gamma-ray bursts) registration and analysis. Averaged count rate in each spectral channel (for the low- energy and high-energy ranges) were approximated by fourth- and five-degree polynomials at the equatorial orbit regions and by parabolic curves and linear functions at the polar ones [11, 12]. Fig. 3 oresents the mean typical latitudinal profiles of the AVS-F counts rate and their approximation in the low-energy (a) and high-energy (b) gamma-bands. Profiles on the equatorial parts of the CORONAS-F orbit are approximated by the fourth-degree polynomials, ones on the polar regions fitted by the linear functions. The energy band 0.1 - 17 MeV corresponds to completely low energy band while regions 0.81 – 0.94 MeV and 2.9 – 3.4 MeV to 10th and 21th channels according to AVS-F calibration for October 2003. The high-energy gamma range of AVS-F apparatus during October, 2003 was from 4 MeV up to 94 MeV.

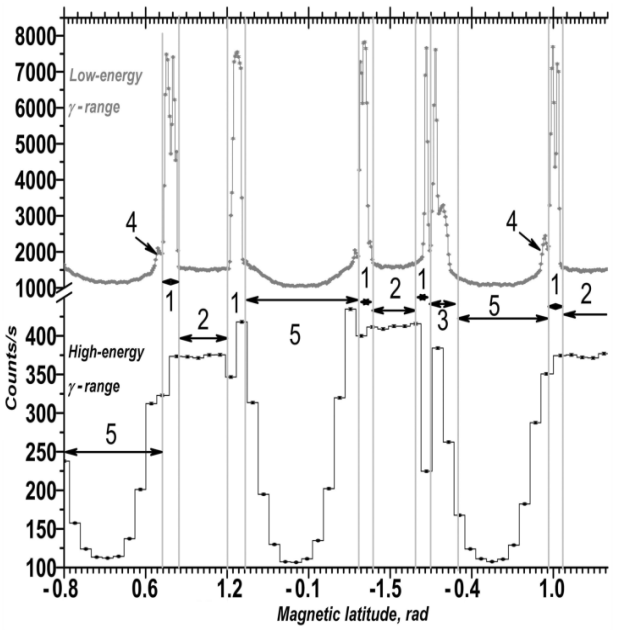

Fig. 2. Typical example of latitudinal profile of the AVS-F counts rate in the low-energy and high-energy gamma-bands.

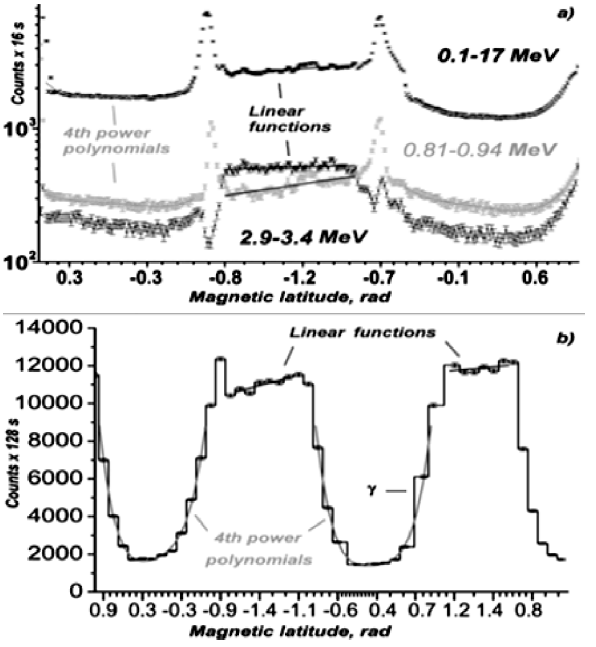

Fig. 3. Typical latitudinal profiles of the AVS-F counts rate and their approximation in the low-energy (a) and high-energy (b) gamma-bands. Profiles on the equatorial parts of the CORONAS-F orbit are approximated by fourth-degree polynomials (orange curves), on the polar parts by linear functions (red lines).

Background polynomials are used to refine the estimated energy of registered during the solar flare spectral features and detailed analysis of their temporal profiles behavior in both corresponding energy bands and summarized energy range. For background analysis several orbits parts were separated in the AVS-F data for this flare in the region of geomagnetic latitude ±5°. The time intervals for background segments were selected taking into

account AVS-F calibration characteristics stability and the absence of powerful solar flares and gamma-ray bursts. The characteristics of background orbit parts are presented in Table 1.

Table 1. The characteristics of background orbit parts.

# of background orbit part	Start	End	Averaged counts rate on equator in the region of geomagnetic latitude ±5° in the AVS-F low energy spectral band	Kp series from -24 to -12 hours before the time of geomagnetic equator passing and <Kp>	Estimated minimum count rate
1	23.10.2003 21:52:44	23.10.2003 22:22:51	810±7	2 2 2 2 2 2.0	820±20
2	24.10.2003 19:36:05	24.10.2003 20:06:12	931±8	2 2 2 2 4 2.4	910±20
3	24.10.2003 21:09:00	24.10.2003 21:39:08	1043±8	2 2 2 4 5 3.0	1030±20
4	25.10.2003 20:25:08	25.10.20 20:55:2003	979±8	3 3 2 2 4 2.8	990±20
5	27.10.2003 20:30:22	27.10.2003 21:00:31	1017±8	3 3 4 3 2 3.0	1030±20
6	30.10.2003 19:53:01	30.10.2003 20:19:21	1681±10	8 7 6 5 5 6.2	1690±20
7	01.11.2003 19:55:33	01.11.2003 20:19:19	1223±9	4 4 5 4 3 4.0	1240±20

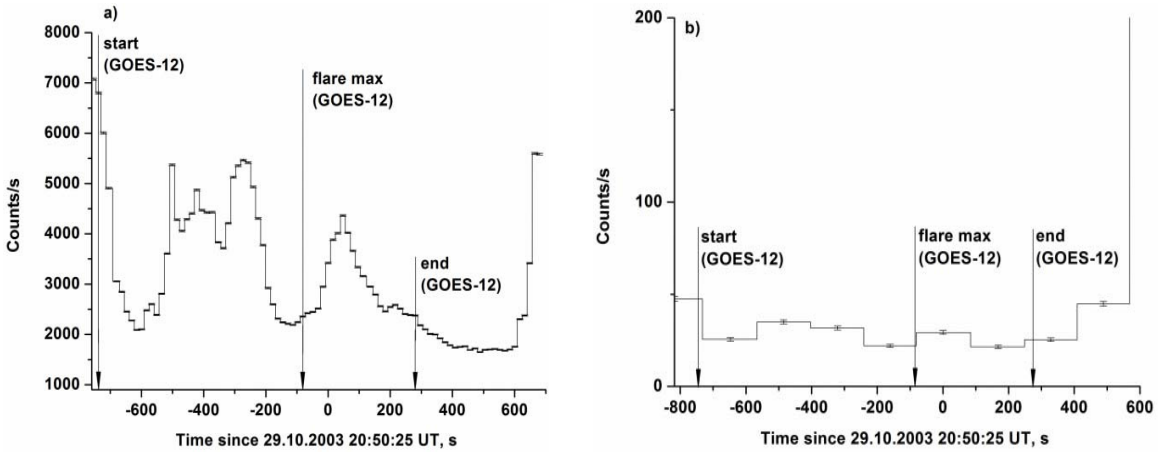

Fig. 4 October 29, 2003 solar flare temporal profiles by AVS-F data in the low (a) and high (b) energy bands without background subtraction.

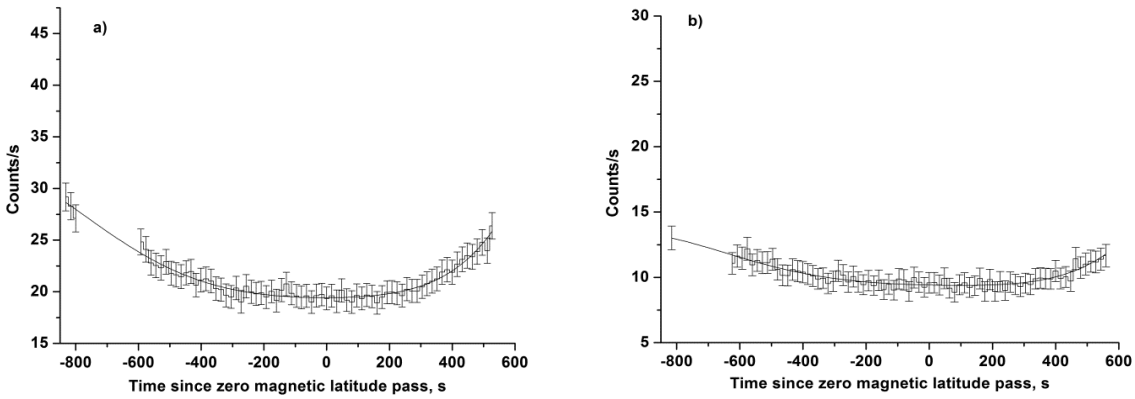

Fig. 5. Background polynomial for averaged on time AVS-F counts rate in 11 (a) and 31 (b) spectral channels.

Than the detector counts rate values in each spectrum channel were averaged for several neighbor orbit parts with similar geomagnetic coordinates following algorithm presented in [12] and corresponding background polynomials were obtained for all AVS-F spectral channels. The AVS-F acquisition time in low energy band is ~16 s and channels started from 67 were summarized 67-70, 71-75 and 76-82 for supply statistical accuracy at 3σ level. Fig. 4 presents the examples of background polynomials for averaged on time AVS-F counts rate in 11 (panel a) and 31 (panel b) spectral channels.

The next step of analysis was the approximation of each selected orbits parts using taken polynomials in both total and each considered spectral channels. The polynomials' coefficients supposed similar for identical spectral channels for each analyzed equatorial part taken into account normalization coefficients defined due to Kp-indexes study. In the first approximation, we have used the linear dependence of estimated minimum count rate value on Kp-index averaged on 5 bins in time interval from –24 to –12 hours before the time of geomagnetic equator passing. The coefficients of this dependence were taken using averaged counts rate on equator in the region of geomagnetic latitude ±5°. The example of calculated results and observed values coincidence for all selected orbits parts presented in Table 1 for AVS-F low energy spectral band.

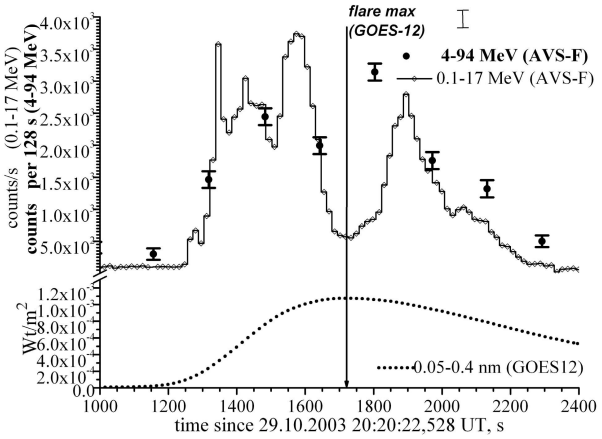

Fig. 6. October 29, 2003 solar flare temporal profiles of AVS-F counts rate in the energy bands of 0.1-17 MeV and 4-94 MeV (with background subtraction) and one of soft X-ray flux accordingly to the GOES-12 satellite data in the band of 0.05-0.4 nm.

The Kp-indexes for October 29, 2003 solar flare from –24 to –12 hours before the time of CORONAS-F satellite geomagnetic equator passing were 4 3 9 8 7 leads to <Kp>=6.2 and normalisation corresponds to minimum count rate values of ~1.7×10^3 counts/s in the low-energy band and ~1.1×10^3 counts per 128 s in the high-energy band of AVS-F. Solar flare of October 29, 2003 temporal profiles with background subtraction in low and high energy bands of AVS-F apparatus are shown at Fig. 6.

4. Conclusion

The procedure of registered by the AVS-F apparatus event temporary behaviour investigation in the various energy bands includes background subtraction in each spectral channel. The low- and high-energy gamma ranges of AVS-F apparatus during October, 2003 were 0.1 - 17 MeV and 4 - 94 MeV correspondingly. AVS-F apparatus background count rate were approximated by polynomials of fifth order taking into account the mean count rate in the geomagnetic equatorial region at the different orbits parts and Kp - index averaged on 5 bins in time interval from –24 to –12 hours before the time of geomagnetic equator passing. The observed averaged counts rate on equator in the region of geomagnetic latitude ±5° and estimated minimum count rate values are in coincidence within statistical errors for all selected orbits parts used for background modelling. This model will used to refine the estimated energy of registered during the October 29, 2003 solar flare spectral features and detailed analysis of

their temporal profiles behavior in corresponding energy bands and in summarized energy range. The special interest feature of this flare is the possibility of lines complex in range of 15-21 MeV registration according to preliminary processing. This spectral feature is similar to one observed during the X7-class solar flare on January 20, 2005 [16, 17]. This complex is the sum of ^{12}C nucleus gamma-emission in 15.11 MeV line and weak wide feature at 20.58 MeV from neutron capture by ^{3}He nuclei [17] and its observation allows to conclude several characteristics of flare area and accelerated particles, for example $n(^{3}He)/n(^{1}H)$ ratio and so on.

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